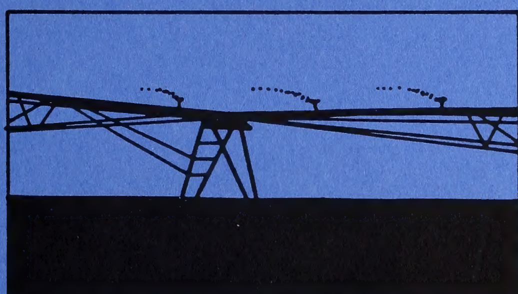
IRRIGATION AND RESOURCE MANAGEMENT DIVISION



Applied Research Report 1997 - 1998

Alberta
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1997-98

Applied Research Report

Irrigation and Resource Management Division

Alberta Agriculture, Food and Rural Development

April 1998

Acknowledgements

I would like to thank the staff members who carried out the research and prepared the reports in this 1997-98 edition of the Applied Research Report of the Irrigation and Resource Management Division. I acknowledge the great effort to plan and carry out these projects. I also appreciate the encouragement and support provided by their supervisors. On behalf of all, I thank the farmers, the funding agencies, irrigation districts, agricultural research associations, agricultural organizations and agricultural service boards for their cooperation.

Special thanks to Hank Vanderpluym and Susan Randolph for compiling and formatting the report.

Brian L. Colgan

Brian L. Colgan, Director
Irrigation and Resource Management

Preface

The Irrigation and Resource Management Division Annual Applied Research Report is a collection of progress and final summary reports. The research is carried out by staff members of the Division and private consultants retained under contract. Research projects vary from detailed tests to field surveys and from irrigation to conservation topics.

The reports are limited in length and summarize the highlights. Detailed data and information are available from the individual researchers. The authors are responsible for the contents of their articles.

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Contents

Alberta Soil Carbon Sequestration Project

Objective(s): The objectives of the project are 3 fold:

1. to evaluate soil organic carbon (SOC) changes in response to a variety of management practices at long-term sites in the six major agroclimatic zones of the province;
2. to verify the Century model for Alberta conditions using available long-term sets; and,
3. to develop an evaluation tool comprising spatial databases and a GIS-Century interface to assess changes in SOC across Alberta Landscapes.

Background: Implementation of the Kyoto Treaty, signed December 1997, will likely direct all sectors of the Canadian Economy to identify and quantify their major sources and sinks (if any) of Greenhouse Gases (GHGs). Of these, the agricultural sector is uniquely positioned to be on the opportunity end of the issue through the enhancement of sinks, in particular, the sequestering of atmospheric carbon into soils. However, quantifying net emissions and carbon storage from non-point diffuse sources common to the agricultural industry, is problematic. Techniques for quantifying net GHG sources and sinks at landscape scales, taking into account the spatial variability and coincidence of land resources and land use need to be developed. This work will become part of a prairie-wide initiative called the Prairie Soil Carbon Balance Project, whose goal is to measure soil organic carbon changes under changing agricultural management practices.

Division Key Results: The enhancement of carbon sinks, facilitated with the estimates from this research, would result in two coinciding benefits to the agricultural industry: (1) reduced net GHG emissions and therefore better air quality; (2) improved/maintained soil quality through increased SOC status. Further, improved soil quality would enhance the agricultural soils' ability to act as a filter and buffering agent leading to improved quality of water in surrounding surface and ground water areas.

Project Description: This three year project is being conducted in two phases. Phase I involves a relative comparison of management practices at selected long-term sites for their ability to sequester carbon using SOC quantity and quality indicators. In addition other parameters are being measured for model verification. The sites are as follows:

Site	Collaborating Scientists
Bow Island – Irrigated Brown Soil Zone	Ross McKenzie, AAFRD
Lethbridge – Dark Brown Soil Zone	Henry Janzen, LRC, AAFC
Three Hills – Dark Brown-Black Transition	John Keng, AAFRD
Ellerslie – Black Soil zone	Noorallah Juma, Bill McGill University of Alberta
Breton –Gray Soil Zones	Noorallah Juma, Bill McGill University of Alberta
Beaverlodge - Dark Gray Soil Zone	Charlie Arshad, AAFC

Treatments at each site were selected on the basis of: (1) presence of a replicated design; (2) relevance of the management practice to the respective soil zone, and, (3) the existence of common treatments between sites. Data is being collected via two routes: (1) historical long-term datasets (includes archived sample analysis) and (2) new collection of SOC storage and model input data. Sampling and lab procedures are standardized for the analysis

according to protocols developed by Janzen and Ellert (1996). Bow Island and Three Hills were sampled in October of 1997 and are currently undergoing analysis. Data from the Lethbridge site are taken from an extensive analysis done in 1992, almost 50 years after the initiation of the experiment. Breton, Ellerslie and Beaverlodge will be sampled in the fall of 1998.

Phase II of the project involves the Landscape Extrapolation-Modeling aspect of the study. The Century model will be thoroughly tested with the data derived in Phase I. Once the model is verified, spatial databases (climate, soil and management inputs to Century) will be assembled and scaled to the appropriate analytical unit (land systems, 1:250,000). Relevant combinations of landscape-soil-climate-management units will be correlated to a spatial concept using a GIS, and the model run on the various units to determine spatial and temporal changes in SOC.

Project Results: The project is barely underway at the time of writing, and no tangible results are available. However, a number of significant steps have occurred in preparation for the project and deserve mention:

1. Development of a Key Indicator Dataset (KIDS) for assessing SOC and soil quality changes as well as key model input requirements
2. Inter-Lab coordination and standardization of a 'Provincial Protocol' for C Cycling Research between the Lethbridge Research Centre and the University of Alberta labs
3. A workshop on Prairie Carbon Sequestration held October 16-18, 1997
4. Documenting the details of the Workshop in a Proceedings (available through C and D Branch)

Conclusions: None as of yet.

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Tom Jensen, Agrium
Aldyen Donnelly, GEMCo (Greenhouse Emissions Management Consortium)

Comparison of Direct Seeding and Conventional Seeding on Soil Microclimate in the Black Soil Zone of Alberta

Objective(s):

1. To compare soil microclimate and early growth conditions between direct seeded and conventional tilled systems at a second Black soil zone site.
2. To compare the effect of two types of seedbed openers on soil microclimate.

Background:

Concerns have been raised by producers in the Black Soil Zone about cool seeding temperatures under reduced tillage systems. Cooler seedbeds have the potential to slow germination and early growth. Disease risk is also increased. Questions have also been raised about the value of soil disturbance in creating a warmer seedbed under direct seeded systems. It has been suggested that high disturbance seedbed openers can generate warmer seedbeds and still conserve soil moisture.

Division Key Results:

Reducing tillage is the most practical way to conserve soil moisture and maintain/improve soil quality (key result 6.1). This project will help mitigate concerns about cool seedbeds and offer some solutions to managing them, leading to higher adoption.

Project Description:

Sites were established at a Sturgeon Soil Savers monitoring site near Fort Saskatchewan in 1995 to compare soil temperatures, moisture and crop growth under direct seeded and conventional tilled systems. In 1997 a similar comparison was established at the Alberta Reduced Tillage Initiative (ARTI) Demonstration farm near Red Deer. In addition a comparison of sites seeded with a Barton disc opener, a low disturbance type, and the Stealth, a knife opener that results in higher surface disturbance were established at the Agrium barley and canola plots on the ARTI farm. This report covers the soil temperature comparisons only. Soil moisture, solar radiation and crop performance data are still undergoing analysis.

Project Results:

The conventional tilled and low residue direct seeded plots had similar soil temperatures in the seedbed depths. The high residue direct seeded treatment had cooler daily maximums and for the early part of the growing season, warmer daily minimum temperatures. The daily temperature range was less than either the Conventional or Low residue treatment (Table 1). The effect is most pronounced during May and early June, when daily maximum temperature differences were as much as 8° C. After June 20 the differences were reduced as the crop canopy began to fully develop.

The analysis covered the period of measurement (May 14 - July 30). The daily minimum temperatures were not significantly different over the period of measurement, however between May 14 and June 20 the low residue treatment was significantly cooler than the High residue treatment. Daily mean temperatures were not statistically different over the period of measurement but were cooler under the high residue treatments prior to June 20.
Seeding with the stealth opener resulted in warmer soils than seeding with the Barton disc opener. The differences were greatest for the daily maximum temperatures at the 5 cm depth, and least for the daily minimum at the 2 cm depth. The trend for warmer soils

following seeding with the Stealth opener was evident for both the barley and canola crops at both depths in both the in-row and between-row locations. The large differences at the 5cm depth are not consistent with the direct seeded-conventional till comparisons both at this site and at Fort Saskatchewan. In those soils the temperature differences are greater at the 2 cm depth and decrease with depth. Fertilizer placement may be influencing the temperature.

Conclusions:

While soil disturbance will influence soil warming, the data from this study suggests that the thickness of the residue layer on the surface is the major controller of soil warming. This suggests that proper residue management in direct seeded system is critical to success. Analysis of the solar radiation data and soil moisture data is ongoing and when completed will help explain the influence of the different residue levels on the seedbed environment.

Comparison of soil temperature between direct seeded and conventional tillage show a consistent pattern of higher daily maximum temperatures in the conventional tilled fields and similar daily minimum temperatures. The result is that conventional tilled soils, while on the average are warmer, experience higher daily temperature fluctuations but similar cooling to direct seeded soils. While the cooler soils under direct seeded systems have the potential to delay germination and early growth, the high daily temperature fluctuations and high maximum temperatures under conventional tilled systems can also be detrimental to crop growth by increasing the risk of heat banding.

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Funding Sources:

Sturgeon Soil Savers, A.R.T.I., Agrium, and the Conservation & Development Branch

Table 1. Means for the daily temperature characteristics in the direct seeded low residue, direct seeded high residue and conventional tilled sites and the A.R.T.I. demonstration farm.

	High Residue	Low Residue	Conventional
Daily Maximum (May 14-Jul 30)	19.1^{B}	21.5^{A}	21.3^{A}
Daily Minimum (May 14 - Jul 30)	11.4	10.8	11
Daily Minimum (May 14 - Jun 20)	13.2^{C}	12.4^{D}	12.7^{CD}
Daily Mean (May 14 - Jul 30)	14.9	15.4	15.5
Daily Mean (May 14 - Jun 20)	16.8^{F}	18.0^{G}	18.0^{G}
Daily Range (May 14 - Jul 30)	7.7^{H}	10.7^{I}	10.3^{I}

Numbers with different letters are statistically different using Tukey's Studentized Range test

Current Irrigation Management Practices - 1996/97 up-date

Objective(s): To determine and quantify, current on-farm irrigation water management practices and how they relate to potential crop consumptive use.

Background: It has been generally accepted that on-farm irrigation water applications have been significantly less than the amount required for optimum production and less than current water allocation licenses. It has also been assumed that irrigation producers use better irrigation management on high cost special crops. In the year 2000 a complete review of all water licenses will be done.

Division Key Results: This project will contribute to improving on-farm irrigation water management and ensure water is not a limiting factor in future irrigated crop production.

Project Description: This is a five year project. During each year of the study, sixty randomly selected fields will be monitored by Irrigation Branch District offices (1997 field sites are shown on the attached plan). Fields are monitored on a weekly basis and the following detailed data is collected:

a) actual, ground level, irrigation and precipitation amounts
b) soil moisture using neutron probe and feel methods
c) soil samples for particle size analysis and moisture holding
d) water table readings
e) irrigation system evaluation to determine design criteria

Project Results: From data collected during the 1996 and 1997 growing seasons, a number of trends have appeared and a number of other hypothesis are showing signs of truth.

Water Requirements:

1 45 % of the fields monitored had a measured crop Consumptive Use - ie. (irrigation + precipitation + (beginning soil moisture - ending soil moisture)- excess water) more than 10% lower than the computer modelled (LRSIMM) crop requirement.

On average, the crops monitored used 52 mm less water than required.

2. The measured and modelled consumptive use of different crops varies considerably. The following table shows the combined C.U. numbers for the 1996 and 1997 growing season.

From these preliminary figures, it is very difficult to determine if special crops get extra water management. Alfalfa seems to be the poorest managed crop but this is due to some producers only irrigating for a two cut operation.

Table 1. Crop Consumptive Use

CROPS (# of Fields)	MONITORED C.U.	% OF MODEL C.U.	MODELLED C.U.
All Crops	378	88%	430
Alfalfa	426	75%	570
Canola	334	95%	352
Barley Silage	313	104%	300
Barley	314	96%	328
Wheat	365	94%	390
Sugar Beets	507	94%	539

3. The amount of irrigation also seems to be very dependent on the amount of precipitation and the climactic area as shown the following table.

Table 2. District Climactic Table

District Office	Irrigation	Precipitation	Total
All Office Average	240	118	358
Strathmore	116	141	257
Brooks	268	102	370
Medicine Hat	238	126	364
Lethbridge	235	118	353
Taber	270	110	380
Bow Island	303	116	419

Irrigation Practices:

1. **Over Irrigation (above 100% available moisture)**

Of all the fields monitored, 23% were over irrigated at least once through the season. The type, or design, of irrigation system in use accounted for 34% of the over irrigation. Operator error accounted for 69% of the over irrigation.

2. **Under Irrigation (under 50% available moisture)**

Of all the fields monitored, 55% were under irrigated at least once during the season. Having an inadequate irrigation system accounted for 12% of the under irrigation. Operator error accounted for 88% of the under irrigation.

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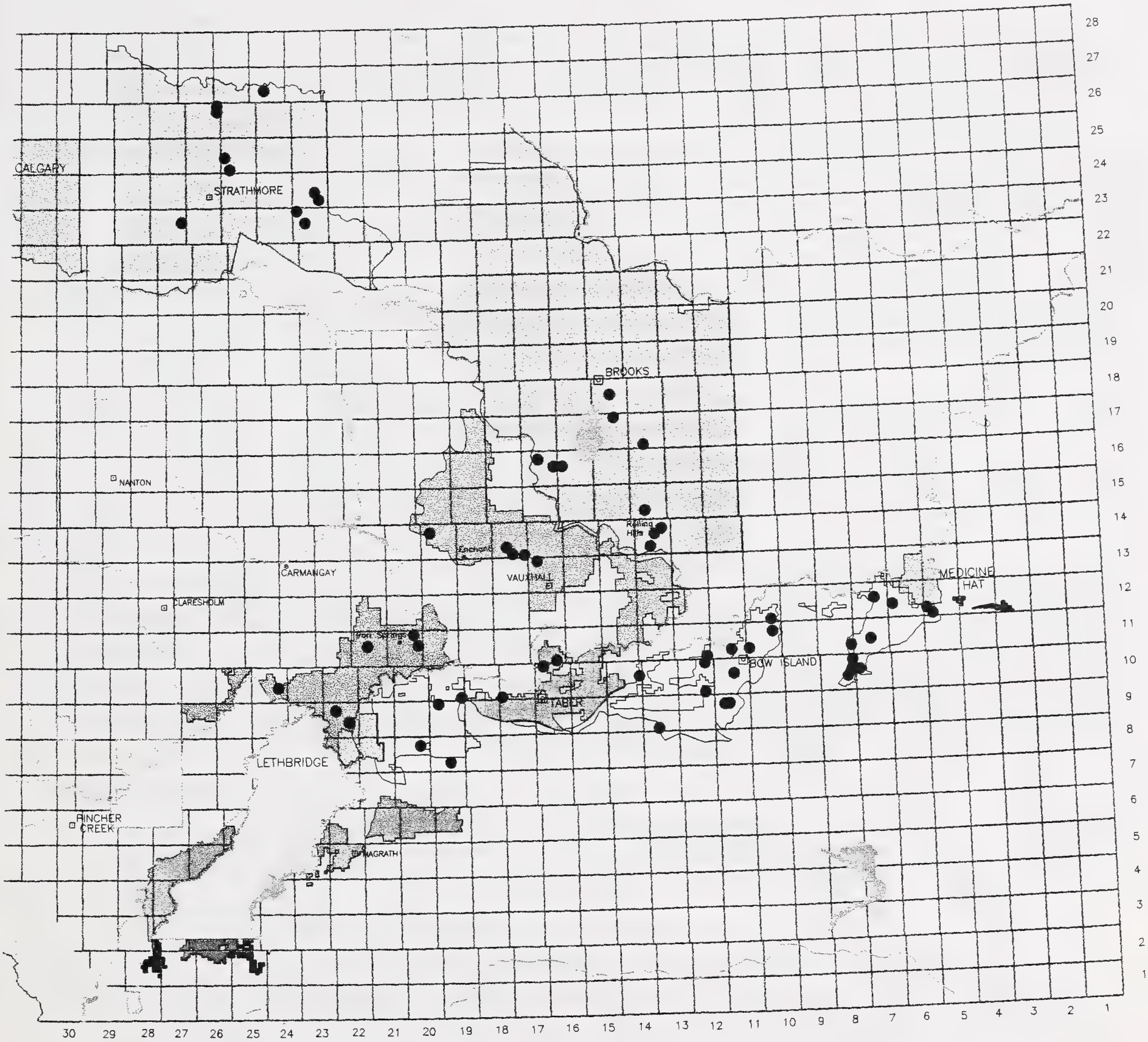
Supporting Agencies: Year 2000 Committee



Alberta

ALBERTA
AGRICULTURE, FOOD
AND RURAL DEVELOPMENT
IRRIGATION BRANCH

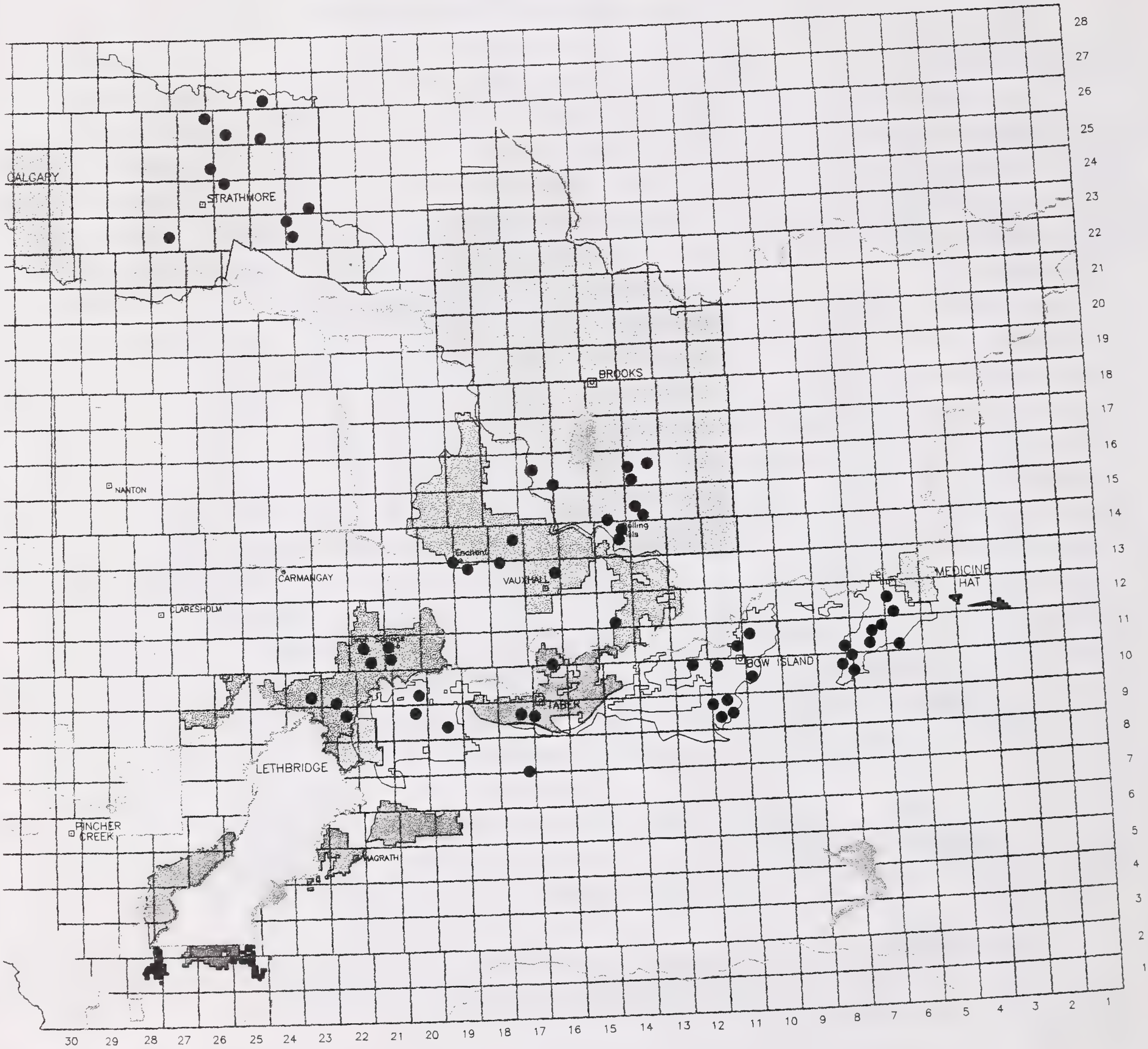
LOCATION PLAN

C I M P MONITORING LOCATIONS 1997

SUBMITTED W.R.CHINN
DATE 1998-02-04
APPROVED
DATE

DESIGNED W.R.CHINN
CHECKED
DRAWN BFC
DATE 1998-02-04

SCALE N.T.S.
SHEET 1 OF 1
DWG. No. X9601102
FILE No.



Alberta	ALBERTA AGRICULTURE, FOOD AND RURAL DEVELOPMENT IRRIGATION BRANCH	LOCATION PLAN
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Direct Seeding Field Crops into Pasture Sod

Objective(s): To determine if direct seeding of annual field crops into pasture or hay land is feasible. To compare the economics of no-till seeding to conventional methods.

Background: There is a need for information on converting hay land into annual field crops using direct seeding practices. Conventional systems have high costs and require intensive tillage which leaves the fields susceptible to soil erosion.

Division Key Results: This project will contribute to improving soil quality by promoting the use of soil conservation practices to convert sod into annual crops. Direct seeding into sod will benefit the producer's land by protecting the soil from wind and water erosion and improving soil moisture management.

Project Description: This project was carried out from 1995 to 1997 on old hay fields. Sites were located on dark grey luvisols in the Warburg area and on black soils at the U. of A. research plots in Edmonton. Each site had three tillage treatments replicated four times in a randomized complete block design. The tillage systems were:

1. Fall/spring applied Roundup with 0.75 L/acre of Roundup and 0.25 L/acre of 2,4-D in early fall, and 0.75 L/acre of Roundup one week before seeding.
2. Spring applied Roundup with 1.5 L/acre one week before seeding.
3. Ploughing the previous fall followed by three to four disc operations, and one pass with cultivator and harrow before seeding.

On each tillage treatment, three crops were seeded: barley, canola, and peas. Two different drills were used to seed each crop in order to compare a low disturbance John Deere 750 disc drill to a high disturbance Harmon air drill.
At Edmonton, the first year sites were reseeded to wheat in the following year to evaluate a second year rotation under direct seeding. The original plough treatment was cultivated in the fall and spring, the two direct seeded treatments were spring sprayed with 1 L/acre of Roundup and 0.25 L/acre of 2,4-D.

Project Results: The average crop yields from 1995 to 1997 are shown in Figures 1 and 2. The results presented are for the Harmon seeder only . Crop yields with the John Deere seeder were not as good as the Harmon. The higher disturbance Harmon seeder seems to create a better seed bed for crop germination and emergence when direct seeding into sod.

For the black soil zone sites in Edmonton, barley yields on the fall/spring and spring sprayed treatments were 84% and 62% of the conventional ploughed treatment respectively. For the grey soil zone sites in Warburg, barley yields on the fall/spring and spring sprayed treatments were 108% and 81% of the ploughed treatment respectively.

There was more grass regrowth in the spring treatments which reduced the barley yields. In the black soil zone, pea yields on the fall/spring and spring sprayed treatments were 100% and 95% of the ploughed treatment respectively. For the grey soil zone, pea yields on the fall/spring and spring sprayed treatments were 103% and 97% of the ploughed treatment respectively.

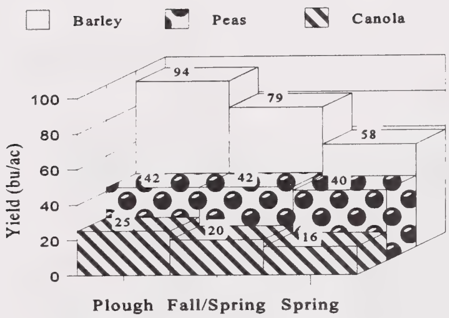

Figure 1: **Average grain yields using Harmon drill in Edmonton 1995-1997**

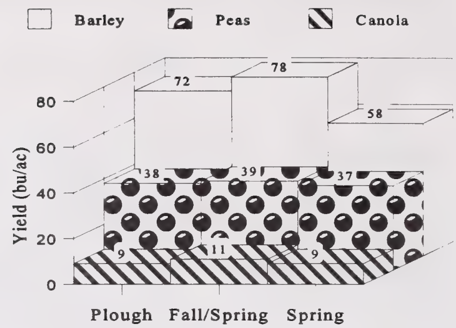

Figure 2: **Average grain yields using Harmon drill in Warburg 1995-1997**

In the black soil zone, canola yields on the fall/spring and spring sprayed treatments were 83% and 66% of the ploughed treatment respectively. In the grey soil zone, the canola yields were so low, that the results are inconclusive.

For the 2nd year sites in Edmonton the average wheat yield (Harmon seeder) on the direct seeded pea stubble was 96% of the yield on the conventional seeded pea stubble. The average wheat yield on the direct seeded barley and canola stubble was 79% of the conventional seeded barley and canola stubble.

Conclusions: The yields on the direct seeded treatments relative to the ploughed treatment were higher in the grey soil zone than the black soil zone for barley and canola. When seeding barley, fall/spring spraying gives significantly higher grain yields than spring spraying alone. Proper timing of a fall application of herbicide is very important in order to have effective control of weeds and sod regrowth. Direct seeding peas into pasture sod produced yields comparable to the conventionally ploughed treatment. Also wheat yields on the 2nd year plots were highest on the pea stubble. Peas are an effective direct seeded crop to use to rotate out of sod. Canola however, did not yield very well using the no-till seeders perhaps due the poor seed to soil contact. Overall the yield results under direct seeding into sod show that it can be a feasible method for converting hay fields into annual field crop production and at the same time providing soil erosion protection.

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Cooperators: Monsanto Canada Inc., Agrium Inc.

Effect of Stubble Height on Moisture Conservation, Soil Temperature and Yield

Objective(s): To compare the effect of three treatments, short stubble with the stubble chopped and spread, tall stubble, and alternate height trap strips on soil moisture, soil temperature and crop yield.

Background: As a result of prolonged drought in southeastern Alberta during the 1980's, considerable interest arose in moisture conservation from of stubble management. CARA initiated a project 1993 to compare practical ways of managing stubble by monitoring their impact on spring soil moisture and temperature, crop performance and economic feasibility. Because of the crop-fallow rotation, yield data has only been collected since 1995. This is the final year of the intense monitoring phase in which Farming for the Future was a partner. The study is planned to continue with realigned plots and less intense monitoring.

Division Key Results: This project will help improve soil quality (key result 6.1) by identifying sustainable management practices that will reduce the risk of poor residue cover brought about by drought and mitigate yields during dry seasons.

Project Description: The site is located six miles south of Acadia Valley in a Brown Chernozem with lacustrine parent material of Heavy Clay texture. The cropping practice is durum wheat-fallow in a strip cropping pattern. The project initial design was 4 replicates X 3 treatments in two adjacent strips. Instrumentation was designed to move to the appropriate strip to collect crop related data yearly.

Project Results: All stubble treatments contained longer standing stubble that other studies and cut residue was chopped and spread evenly over the surface. This resulted in no clear advantage in using alternate height stubble trap strips. Tall stubble trapped as much snow and both the tall and short stubble treatments had as much or more overwinter gains that the trap strips (Table 1). There was also no yield advantage in the trap strips. In the south strip, which was cropped during 1995 and 1997 the trap strips had significantly lower yields (Table 2) and significantly lower moisture gains from the previous winter. This effect was not repeated in 1996 when the north strip was cropped.

Table 1. Overwinter soil moisture gains in the top 60 cm under tall short and alternate height stubble at the Acadia Valley plots. Overwinter gains from 1996-97 were not measured due to excessively wet field conditions

overwinter gain (mm)*	Tall Stubble	Short Stubble	Alternate Height
1993-94	3.2^a	3.4^a	1.1^b
1994-95	23.7^a	33.5^a	20.1^a
1995-96	87.6^a	80.0^a	63.8^b
Precipitation	Nov 93-May 94	Nov 94-May 95	Nov 95-May 96
	70 mm	79 mm	93 mm

Cold, wet weather during the fall and spring coupled with snowmelt runoff patterns masked some of the snowtrapping benefits. Plot position and wet seeding conditions appeared to

control yields in the north strip during 1996 (Table 2). In the south strip there was a clear relationship between nitrate levels at seeding and yield, and also some evidence to suggest that ponding contributed to the lower nitrate levels by enhancing denitrification. There was no effect of the stubble treatments on soil temperature.

Table 2. Average yields (kg/ha * 1000) of durum wheat on fallow for three stubble treatments

Yield*	TALL	SHORT	ALTERNATE HEIGHT
1995 South Strip	3.08[a]	2.99[a]	2.55[b]
1996 North Strip replicates 3&4 / 1&2	3.07[a] / 3.03[c]	3.09[a]/ 2.49[d]	3.03[a]/ 2.85[c]
1997 South Strip	2.34[a]	2.30[a]	1.69[b]

* different letters within any year indicate significance at 5% level (Tukey's studentized range test).

A new treatment of short stubble with the cut residue baled and removed is being examined. Preliminary results suggest that removal of the surface mulch leads to faster warming and drier surface condition. No crop has been grown on these plots at this time.

Conclusions:

The results show that good residue management is effective in conserving soil moisture in the Heavy Clay soils in the Brown soil zone regardless of the type of standing stubble. The extra length of the standing stubble in the tall and short stubble, and the chopping and even spreading of the cut residue on the short plots resulted in similar overwinter gains. Although surface ponding of snowmelt runoff make direct comparisons difficult, it is apparent that even though short stubble does not trap as much snow as tall stubble or trap strips, it makes little difference to the spring moisture levels in many years. Often there is not enough snowcover to fully take advantage of the tall stubble and the mulch created by the even spreading of the cut residue reduces loss from evaporation.

From these results it is recommended that the most practical way to conserve soil moisture is to leave the stubble as long as possible, preferably by straight cutting. If swathing, proper chopping and spreading of the cut residue is essential to good moisture conservation. Alternate height trap strips may only be beneficial effective when conditions dictate that the stubble must be cut short.

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Funding Sources: FFF Project No. 930318

Evaluation of the WEPP Model at the Tofield Research Site

Objective(s): To evaluate Water Erosion Prediction Project (WEPP) model under Alberta soil and climate conditions.

Background: The USDA Water Erosion Prediction Project (WEPP) model can evaluate the impacts of conservation tillage, crop rotations, crop residue management, and the use of tillage implements on soil loss on agricultural land.

Project Description: Detailed descriptions of Tofield data acquisition and site instrumentation are included in the "CAESA Soil Quality Water Erosion Research Annual Report 1994/95 (Jedrych et al.)." The Tofield site consists of two 4.2 x 40 m plots and two watersheds. The east and west watersheds have 0.50 and 0.55 ha drainage areas respectively. The 97.3 version of WEPP was used in the two year simulation. The model required four input files: climate, soil, land use, and landscape data. The climate input file was prepared using data measured at the site and existing data from adjacent climate stations. The soil input file was prepared based on the soil mechanical analysis and infiltration tests conducted at the research site. The soil erodibility parameters for the top soil layer were estimated using WEPP equations (Flanagan and Nearing, 1995). The land use input file assumed the same crop yield on both watersheds and plots under spring tillage and seeding conditions. The slope input file was prepared based on a detailed topographic survey of the research site.

Project Results:

WEPP simulations and statistical analyses

Continuous WEPP simulations were conducted separately for the east and west watersheds and two plots.

First order polynomial regression was used to analyse the correlation between measured and predicted summer runoff events and soil loss on the two plots and watersheds. The coefficient of determination ($\mathbf{R}^2$) was calculated for the best-fit regression line.

WEPP's predicted runoff and soil loss events had $\mathbf{R}^2$ ranging from 0.34 to 0.60. The erosion plots had much higher $\mathbf{R}^2$ values than the watersheds. This can be attributed to a higher variation in soil and crop conditions on watersheds than on plots. Also, the hydrologic conditions on these two watersheds are quite different. The east watershed is more concentrated than the west one. The $\mathbf{R}^2$ value for east versus west plot was 0.90 compared with 0.74 for east versus west watershed.

Conclusions: Our study showed that the snowmelt subroutine in the WEPP model still needs improvement. The model predicted only a one day spring runoff event in 1995 and 1996 instead of eight and nine days respectively. The predicted events were under frozen soil conditions and therefore the model underestimated soil loss by more than 90% in both years. Despite this, the predicted dates for the spring runoff events better correlated with the measured ones in the 97.3 model version than in the previous versions.

Generally summer runoff events were predicted much better. Although, the model

underestimated runoff and soil loss on erosion plots and watersheds, it is too early to attribute this only to the model prediction. Another factor that largely affects model output is the initial entered value for the saturated hydraulic conductivity (**K**sat). In our study the **K**sat of the soil top layer measured in field varied from 0 to 10 mm/hour. In the simulation **K**sat was assumed to be 0.3mm/hour (J. Tajek communication). Since **K**sat greatly impacts WEPP model output, more study is needed to better understand the Solonetzic soil infiltration conditions.

The above regression results are based on WEPP simulation using the special format of the soil input file. This format required, as additional inputs, consolidated bulk density, saturated hydraulic conductivity (**K**sat), water content at field capacity, and wilting point . The regular format soil file does not require this data and gave less satisfactory results, and was therefore not included in this report.

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Foxtail Barley Seed Head Suppression and Control

Objective(s): To obtain minor use registration for Roundup to suppress seed head development of foxtail barley.
To obtain minor use registration for MON 37500 to control foxtail barley in perennial forage stands.
The evaluation of cultural methods to suppress seed head development of foxtail barley.

Background: Foxtail barley Hordium jubatum L. is a native of North America and is especially common in saline and alkaline soils (Weeds of the West pp459). Foxtail barley is a short-lived fibrous rooted perennial bunch grass, without rhizomes. It reproduces by seed and forms clumps with much branching from the base. The single leaf blade is 0.3 to 0.6 cm wide. The sheaths may vary from smooth to densely hairy. The plant produces a seed head in June and July and seeds mature from July through September. At maturity the heads break into 7-awned clusters consisting of 3 spikelets of which one is fertile and 2 are sterile. Spikelets are 1-flowered. Awns are 2.5 to 5 cm long (Nebraska Weeds pp5-7). The awns have a sharp point near the base with minute barbs that point away from the base so they act similar to a porcupine quill. These seeds can attach to the lining of the mouth and eyes of livestock and result in irritation to the animals. Foxtail barley is a prolific seed producer and because of the long awns can be spread easily by the wind (Weeds of the West).

Foxtail barley causes millions of dollars in losses by reducing forage yield and quality as well as in livestock operations from irritation of the lining of the mouth and eyes of animals being fed contaminated hay. Saline areas are often contaminated with foxtail barley and other salt tolerant weeds like kochia. Farmers practising salinity control with salt tolerant forages requested that efforts begin to find a non-cultural control foxtail barley in saline areas.

Division Key Results: MON 37500 is a selective grass herbicide that shows promise in controlling foxtail barley in perennial forage stands. Roundup is a non-selective herbicide that at low rates suppresses the reproductive stage of the plant and encourages the vegetative stage. Applications of Roundup at the low rates recommended will delay development of foxtail barley seed head.
This project will contribute to improving soil quality by encouraging forage production on saline soils. This will benefit the soil by stabilizing the saline seep, lowering water tables and preventing wind and water erosion.

Project Description: Three research sites and four demo sites were selected for this study. Research Site 1 is at the Monsanto Research Farm. Research Site 2 is in New Daytona dn Research site 3 is in Warner. The four demo sites are located in the County of Lethbridge, Warner, Newell and the MD of Cypress.
MON 375000 was applied at three rates and at three time intervals. A fall dormant application, an early post application and a late post application. The Roundup was applied at three rates at the late post and just before first cut periods.

Project Results: MON 37500 had the best control of foxtail barley at all three rates. The dormant

application had the least crop injury. The early post had minimal crop injury but the late post showed signs of severe crop injury.
The Roundup showed no crop injury at the three rates and at the two time periods. The early application gave better seed head suppression of foxtail barley than the late application.
A cultural control project is being developed in conjunction with the herbicide application in order to give another option to producers to manage forage stands contaminated with foxtail barley. Mowing of the foxtail barley will begin in early June and be carried out weekly until harvest occurs.

Conclusions: MON 37500 shows promise as a selective herbicide for foxtail barley control in perennial grass and legume stands. Roundup delays the heading of foxtail barley and also shows control of seedling foxtail barley plants. Mowing is similar to forced grazing and should have the same effect when applied to hayland.

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Research Support: Counties of Warner, Lethbridge, and Newell and MD of Cypress
Southern Applied Research Association

Funding Sources: Alberta Environmentally Sustainable Agriculture Program

Hydrology of a Feedlot

Objective(s): To measure rainfall, runoff and infiltration on blocks of feedlot pens to characterize runoff events and runoff volumes.

Background: Alberta's Code of Practice for the Safe and Economic Handling of Animal Manure recommends that feedlots with over 300 head have catch basins to store run-off from pens. Alberta based criteria was not available for calculating catch basin volumes.

Project Description: Highland Feeders is a recently constructed feedlot with a well planned drainage system. The pen areas are discrete watersheds, defined by the feed bunks at the outside of each block of pens.

Each pen area includes two strings of pens that back onto a central drain flanked on both sides by travel alleys. Each central ditch drains south at a slope of one percent to a 160,000 m^3 pond. Each pen has a slope of 2.5 percent to the central ditch at the back of the pen.

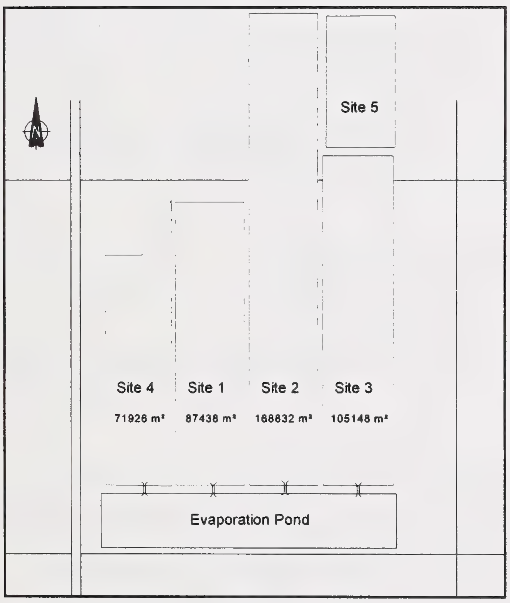


Figure 3 Layout of Highland Feeders Feedlot

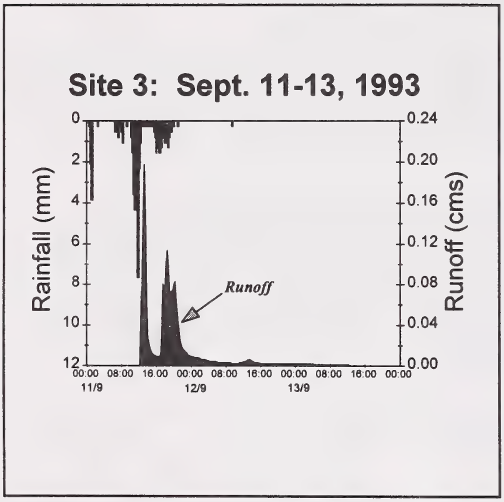
Weather and run-off measurements began in July 1993 on Pen Areas 1 and 2. Water quality sampling was added in May, 1994. Additional sites were added in 1994 (Pen Area 3), 1995 (Pen Area 4) and 1996 (Pen Area 5). Weather and run-off measurements have continued through 1997 and 1998.

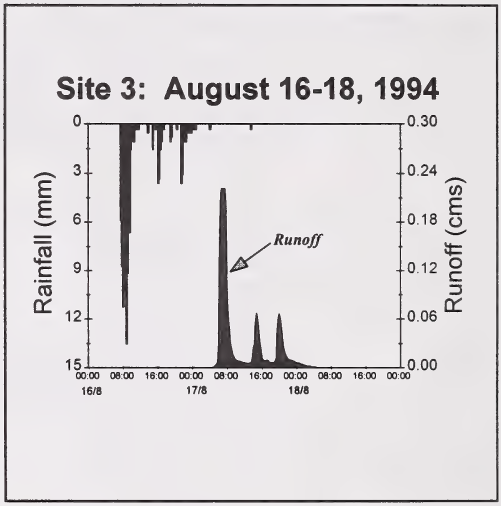
Project Results: The Site 3, Sept. 1993 hydrograph shows the response of a newly constructed pen area before cattle had been moved in. Lag times are shorter for this event. The August 1994 event for this same site shows a run-off response similar to other sites, indicating how quickly the pen area's detention storage developed once cattle were in the new pens. There are no snowmelt events. The feedlot pens are cleaned just before snowmelt and the combined snow and manure is stored just above the catch basin.

Infiltration tests on three year old pens proved that infiltration was zero once the manure layer above the manure/clay hardpan interface was saturated. The average to reach zero infiltration was eight days.

Table 1: Rainfall & Run-off Response (for storms with return period > 1:10 years)

	Rainfall (m^3)	Run-off (m^3)	Lag (hr)	Yield (%)	SCS CN (No.)
Minimum	6,089.3	1,662.3	7.0	15.9	55.1
Mean	13,063.9	3,541.9	24.6	27.7	67.7
Maximum	20,227.2	6,915.6	47.5	39.3	83.1
Coeff. of Variation	0.41	0.48	0.48	0.27	0.13





The SCS Curve Numbers range between 55 and 83 in contrast to the SCS Curve Number of 91 recommended in American literature for estimating run-off from unpaved feedlots for average moisture conditions.

Conclusions:

Feedlot pens with active use have hardpans that severely restrict infiltration of water below the manure layer. The manure layer has substantial storage capacity that combined with Alberta's semi-arid climate usually means that individual storms have a significant moisture reservoir to fill before run-off begins. Antecedent moisture is the determining factor for predicting a run-off event. Rather than sizing catch basins to severe single event storms, run-off yields from a critical wet year are design criteria more appropriate to current management. The Alberta Feedlot Management Guide now uses wettest year rather than critical storm for sizing catch basins.

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Snowfluent® Treatment of Food Processing Wastewater

Objective(s): The Snowfluent® trials had four questions: how much of the nutrients are removed from raw malting effluent by the Snowfluent® process, how is treatment achieved, during snow making, in the snow pack and at snowmelt., what is the effect on soil and shallow water tables in land application of Snowfluent®, what are the levels of airborne bacteria (bioaerosols) in the air during snowmaking, and do these levels present any health risk to operators and neighbours.

Background: Treatment of food processing wastewater has two problems. Organic matter content is much higher than municipal wastewater. Decomposition of organic matter in lagoons is anaerobic resulting in objectionable odours. Conventional treatment systems cannot handle the high levels of nutrients and organic matter in the wastewater.

Project Description: Snowfluent® is a new Canadian wastewater treatment technology developed by Delta Engineering, Ottawa, that uses modified snow making guns to treatment municipal and industrial wastewater. Tests by Ontario Ministry of the Environment showed primary sewage had reductions in contaminants to the point that the snowmelt could be discharged to streams. A significant odour reduction was noted.

Delta Engineering's portable snow making plant (two semi-trailers) was brought in late February, 1997, to the Alberta Research Council, Vegreville. Two 2 metre snow piles were built on a lined plot and a unlined plot. Both plots measured 15m X 15 m. Raw wastewater from Westcan Malting, Alix was hauled by tankers to Vegreville. H-flumes were installed at the outlets of the bermed plots. Fresh and aged snow samples were collected as well as lagoon water, meltwater and aerosol samples at snow making.

Results: Snowfluent® significantly improved malting plant wastewater quality. Odours from the snow pack and the meltwater were much less than from lagoons. There were odours during the snow making operation but they were minimal at a distance of 30 metres from the plume. The best snow making conditions are at night and on cold days which reduces the public exposure to snow plume odours.

Soil sampling was limited. Before and after soil sampling showed no significant changes. Sodium, SAR, and Electrical Conductivity (EC) levels were lower in the soil samples in June than in January.

Total Phosphorus (TP) in the treated meltwater exceeded Alberta's Ambient Surface Water Quality Interim Guidelines of 0.15 mg/L for TP. Meltwater should not drain to surface water courses.

Table 1: **Mean Concentration of Biochemical Oxygen Demand, Dissolved Organic Carbon, Total Kjeldahl Nitrogen, Total Phosphorous, and Faecal Coliforms During the Snowfluent Process.**

Parameter	[Raw Effluent]	[Fresh Snow]		[Run Off]		Total Percent Decrease	
		lined	unlined	lined	unlined	lined	unlined
Biochemical Oxygen Demand (BOD) (mg/L)	2437	1753	1285	146	32	94%	99%
Dissolved Organic Carbon (DOC) (mg/L)	1005	974	596	54	12	95	99
Total Kjeldahl Nitrogen (TKN) (mg/L)	85.7	75	45	11.9	9.9	86	88
Total Phosphorous (TP) (mg/L)	38.2	24	26	15.3	12.6	60	67
Faecal Coliforms (FC) (CFU/100mL)	6.76×10^{6}	7.43×10^{4}	1.22×10^{5}	7	2	5 log (99.999%)	5 log (99.999%)
Equivalent Water Volume (L)	497053	133680	146039	96290	55729	60%	82%

The interpretation of groundwater impacts from this pilot study is limited because of the lack of background groundwater samples, upslope groundwater samples, and the likelihood of surface water contamination of the deepest (2.4 metres) sampling wells. For a two metre deep snow pile, snowmelt did not infiltrate below typical crop rooting depths, except where meltwater had ponded. Water samples met the Canadian Drinking Water Guidelines for nitrate. Faecal coliform guidelines were not met, although no faecal coliforms were detected after snowmelt stopped.

Based on the limited data collected, bioaerosol levels beyond 100 metres downwind from the snow gun were indistinguishable from background levels, and well below any level of concern for both operators and neighbours.

Conclusions: Snowfluent® treatment meets draft guidelines for land application by effluent irrigation. On many parameters, surface water quality guidelines are met, but some key parameters such as TP are exceeded. Runoff from the snow pack should not leave the field boundaries where Snowfluent® is applied. Within the limits of this pilot study, Snowfluent® technology is a viable alternative for food processing wastewater in Alberta.

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Supporting Agencies: Alberta Environmentally Sustainable Agriculture, Processing program

Snowfluent® Treatment of Liquid Hog Manure

Objective(s): The Snowfluent® trial had three questions: what degree of treatment is achieved using Snowfluent® to treat liquid hog manure, how is treatment achieved during snow making, in the snow pack and at snowmelt and what are the levels of airborne bacteria (bioaerosols) in the air during snow making, and do these levels present any health risk to operators and neighbours.

Background: Treatment of liquid hog manure has two problems. Decomposition of organic matter in lagoons and pits is anaerobic resulting in objectionable odours. Large volumes of liquid manure are costly to haul for land spreading. Separation and purification of the water fraction would be a logical option but conventional treatment systems cannot handle the high levels of nutrients and organic matter in the wastewater.

Project Description: Snowfluent® is a new Canadian wastewater treatment technology developed by Delta Engineering, Ottawa, that uses modified snow making guns to treatment municipal and industrial wastewater. Tests by Ontario Ministry of the Environment showed primary sewage had reductions in contaminants to the point that the snowmelt could be discharged to streams. A significant odour reduction was noted.

A portable snow making plant (two semi-trailers) was brought by Delta Engineering in late February, 1997, to Dana Giebelhaus' 300 farrow to finish operation, 20 km. southwest of Vegreville. A two metre snow pile was built on a lined 15m X 15 m plot. Lagoon water was drawn off without agitation just below the lagoon's ice cover. An H-flume was installed at the outlet of the bermed plot. Fresh and aged snow samples were collected as well as lagoon water, meltwater and aerosol samples at snow making.

Project Results: Odours are noticeably reduced. Odours from the snow pack are much less than from lagoons. There are minimal odours in the meltwater. The solid residue has noticeably less odour than liquid or solid manure. There are odours in the immediate vicinity of the snow plume. However, the best snow making conditions are at night and during cold weather.

In one treatment, Snowfluent® does not remove enough of the nutrients and contaminants for the meltwater to be released to surface water. However, the meltwater should be suitable for re-use in the barns for manure flushing or irrigating a crop. Alternatively, additional treatment in conventional lagoons may improve the water quality to the point of meeting regulatory limits for surface water discharge.
Ammonia is lost to the air at snow making and in the snow pack. This results in 70 to 80% of the liquid manure's nitrogen content being lost.

Table 1: **Typical Concentration Reductions During the Snowfluent Process.**

Parameter	Raw Manure (n = 3)		Fresh Snow (n = 5)		Runoff (n > 6000)		Net Reduction
	Mean Concentration	±SE	Mean Concentration	±SE	Mean Concentration	±SE	
Biochemical Oxygen Demand (BOD) (mg/L)	6524	76	6925	49	3360	55	48%
Total Kjeldahl Nitrogen (TKN) (mg/L)	2431	240	2462	126	946	15	61%
Inorganic Nitrogen (NO_2+NO_3) (mg/L)	1.244	0.173	0.866	0.135	0.141	0.002	89%
Total Phosphorous (TP) (mg/L)	424.5	43.7	329.3	32.1	131.0	1.6	69%
Faecal Coliforms (FC) (CFU/100mL)	6.71×10^6	5.61×10^5	4.63×10^5	3.34×10^5	27	<1	5-log (99.999%)
Equivalent Water Content (L)	212,906		91,000		82,000		

Snowfluent® is effective in decanting water from solids for liquid manure systems that do not use straw. The solid residue has a nitrogen and phosphorus concentration higher than poultry manure.

An economic comparison of Snowfluent® with conventional spreading and injection methods of manure management finds that it is comparable in cost. However, it provides only winter treatment.

Snowfluent® appears to fit into a conventional liquid manure management system without significant changes to equipment and layout.

Conclusions: Overall, Snowfluent® offers Alberta pork producers an opportunity to eliminate odour from lagoons and manure spreading. By decanting water from solids, it could reduce manure spreading costs and land requirements. Snowfluent is effective in killing micro-organisms. It could reduce water requirements by allowing the decanted water to be recycled to the barn for manure flushing. Snowfluent treatment losses nitrogen through ammonia volatilization. The pilot test justifies production scale tests to define the best operational processes and test options that may retain more ammonia in the solids.

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Supporting Agencies: Alberta Pork Producers Development Corporation, Delta Engineering, Alberta Research Council, Alberta Agriculture, Food and Rural Devevelopment

Sustainable Cropping Systems Research Study (SCSRS): Three Hills Site

Objective(s): The overall objective of this component of the SCSRS is to evaluate the long-term effects of suitable cropping systems on the productivity of soils in the Dark Brown-Thin Black Transition soil zone (Three Hills site). A number of sub-objectives are being addressed:

To compare the effect of rotation on wheat yields; grain nutrient uptake of N, P, K and S; and soil fertility;

To evaluate the effect of tillage on wheat yields; grain nutrient uptake of N, P, K and S; and soil fertility.

Background: Farm managers need sound, scientific research to make informed, knowledgeable management decisions for their particular soil/climatic zone. A rotational study was initiated in the spring of 1991 in the Dark Brown – Black transition soil zone to gather information on suitable cropping systems for this region. A total of nine crop rotations are available for comparison and, in the fall of 1994, the study incorporated a comparison of direct seeding and conventional tillage. The research conducted at this site is intended to complement the studies being done at other sites in the SCSRS network. These include Lethbridge (dark brown soil zone); Ellerslie (black soil zone); Breton (grey soil zone); Bow Island (brown soil zone); and Beaverlodge (dark grey soil zone).

Division Key Results: This study contributes to sustained or enhanced soil quality by identifying management practices that sustain the land base. The results will support producers decisions when considering management options in this agroclimatic zone.

Project Description: This study site, located next to the Three Hills airport, is a 10 acre parcel of provincially owned land in the M.D. of Kneehills. The experimental design consists of 20 main plots per each of the three replicate blocks. The 20 main plots are randomly assigned and represent specific phases of each crop rotation:

1 - Continuous **wheat** (CW)
2 - Canola-barley-peas-**wheat** (CBPW)
3 - **Wheat**-fallow (WF)
4 - **Wheat**-green manure (peas) (WGm)
5 - **Wheat-wheat**-fallow (W_1WF and WW_2F)[1]
6 - Peas-**wheat**-fallow (PWF)
7 - Continuous Brome grass (G)
8 - Continuous Alfalfa and Brome grass (AG)
9 - **Wheat**-peas and oats silage-fall rye (WP/OR)

Each plot is split into two tillage treatments, conventional and direct seeded (reduced tillage). In the spring of 1997, all plots (except legume and forage-based rotations) received a blanket application of macronutrients. **Since each phase of every rotation is seeded annually, data from the wheat phases were used to compare tillage and rotation effects on measured variables (bolded above).**

Project Results: Rotation has had a significant effect on wheat yields over the last three years but the magnitude and direction of the impact varies with available moisture (Fig. 1). In wet years (1995), benefits from extended crop rotations like CBPW are obvious – they out-yield continuous wheat rotations and due to a crop being harvested annually, are less

[1] W_1WF – represents the first year of wheat and WW_2F represents the second year of wheat in the wheat rotation.

risky than fallowed rotations.

However, in much drier years (1997), the advantage of a fallow year becomes evident—the continuously cropped rotations yielded half or less that of the wheat following fallow phases. Grain nutrient uptake (kg ha^{-1}) roughly followed the yield patterns. In general, fall soil fertility tended to be higher in the legume containing rotations. Overall, those rotations containing a year of fallow tended to have lower soil fertility. After the third year of direct seeding (1995-1997), wheat yields were significantly higher than the conventionally managed plots (150 kg ha^{-1} overall or 2.2 bu ac^{-1}).

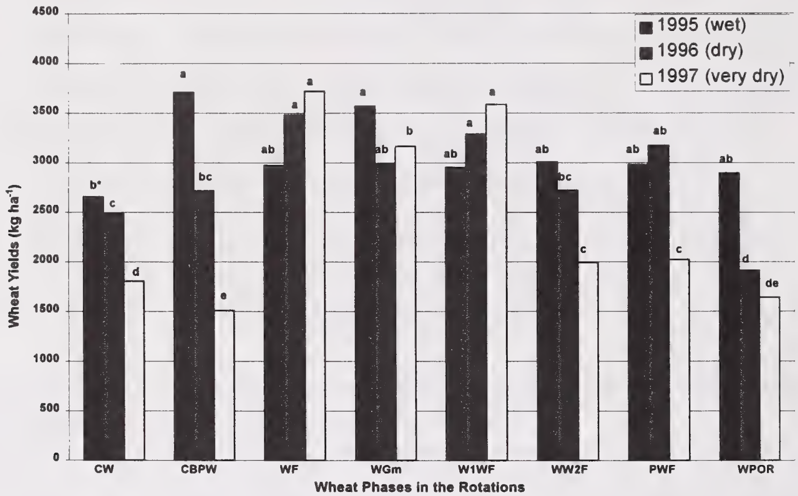

Figure 1. Wheat yields of each rotation's wheat phases for 1995, 1996 and 1997 crop years (averaged across tillage systems). Statistical comparisons are valid within a given year between rotations (P=0.05).

Conclusions: Extended, diversified rotations may offer less risk in this agroclimatic zone, since the impact of rotation appears to be highly influenced by available moisture. The preliminary results indicate that direct seeding is changing the soil nutrient dynamics and productivity of the soils. Pulse containing rotations tend to have higher soil fertility which wheat grown on pea stubble yields well when available moisture is adequate.

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Cooperators: Tom Jensen, Agrium

Yield Response to Nitrogen within a Strongly Rolling Landscape

Objective(s): To test whether landscape type can be a basis for separating a field into different management areas for precision farming.

Background: Precision farming is the practice of tailoring farm inputs to match different growing conditions within fields. It has the potential for more economical and environmentally friendly management than current blanket applications of inputs. However, varying inputs requires an idea of where to apply what rate of input. One of the promising aspects of precision farming is nitrogen (N) fertility management. Is there an optimum N rate for knolls that is different from the rest of the field? How do we know how much N to apply to each area of a field?

Division Key Results: Improved soil quality is based on improved farm management. This project improves our understanding of what are appropriate rates of N to apply to which areas of a farmer's field. Appropriate N rates will reduce the impacts of excess N on water quality.

Project Description: Our test field near Hussar has 80 ac of strongly rolling topography, fine textured clay loam soil and 20 years of direct seeding. We separated the field into five landscape types: knolls or shoulderslope; depressions or footslopes; backslopes; and, level areas that we further divided into upper and lower. We used yield measurements within strips of different fertilizer rates across a field as a means of measuring response to N within the different landscape types. Yield monitors and differential global positioning systems were used to measure and locate yield.

Project Results: The 1996 canola yield responses to 0, 30, 60, and 90 lb/ac of N within each landscape type at Hussar are presented in Figure 1. Clearly, landscape affects yield. The unfertilized yield was twice as high on the footslopes as on the shoulderslopes, indicating the lower fertility of the soil on the shoulderslopes.

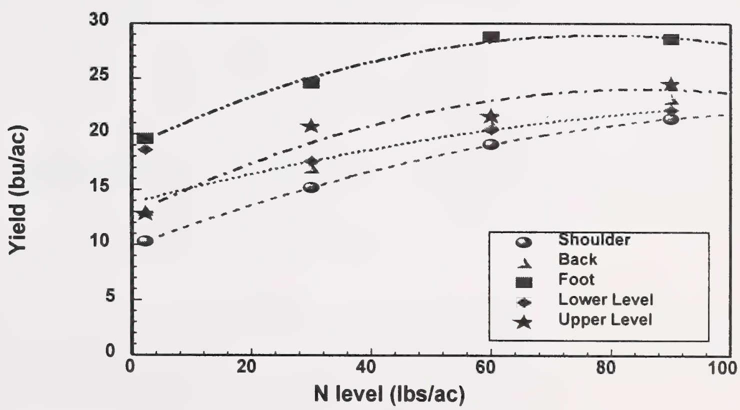

Figure 1. Canola response to N within landscapes at Hussar.

Yield increased with increased N for all landscapes, and the benefit of higher N rates was less at greater rates of N. However, the yield increase on the footslopes levelled off much sooner (at about 60 lb/ac N) than the curves for the backslopes and shoulderslopes (at about 100 lb/ac N). These results show that canola responded differently to N within landscapes and that ideally, N should be managed differently in each landscape.

The basis of any management analysis is to apply N at the most optimum rate. An optimum N rate occurs at the point where the incremental costs of additional N are not recovered in increased yield. For the field near Hussar we used the 1996 N cost of $0.33/lb and canola price of $0.16/lb. In this case, the optimum N rate for the footslopes was 66 lb/ac, for the backslopes, 114 lb/ ac, and for the shoulderslopes, 96 lb/ac. Note that these amounts on fine textured clay loam soil may be excessive on a sandy soil. If we varied N according to landscape, the additional profit would be about $3/ac compared with putting the same amount of N evenly over the whole field (at 95 lb/ac). Compared with applying the farmer's rate of 60 lb/ac evenly over the field, the additional profit from optimally varying fertilizer was about $7/ac. We would expect these numbers to change according to climate, the price of N, and crop prices.

On a different area of this field in 1995, the pattern of wheat yield and its response to N was similar to that in 1996 (in similar growing season rainfalls and temperatures). The yields were again lowest on the shoulderslopes, and highest on the footslopes. When we calculated the optimum rate of N for each landscape, we again found that the backslopes and shoulderslopes required the highest amount of N and the footslopes the lowest. In 1995, the net benefit of applying the variable rates over uniform rates was about $11/ac.

Conclusions: We've found that landscape provides a basis for variable rate N fertilization and that there's potential for profit in this practice. But will the patterns that we identified in retrospect,with perfect knowledge of weather, economics and yield, be useful in planning a management scheme next year, where we have no certain knowledge of any of these factors? How can a farmer identify a profitable management strategy that is specific to his field? How long must a new management scheme be tested before committing to treating an entire field with varying rates of fertility? We're continuing to work to help answer some of these questions.

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Yield, Rooting Depth and Soil Water Use of Alfalfa in the Brown, Dark Brown & Black Soil Zone of Alberta

Objective(s): The evaluation of twelve alfalfa cultivars inorder to develop reliable recommendations on yield, rooting depth and soil water use for soil salinity control.

Background: Alfalfa is recommended for recharge areas to control dryland salinity by reducing local groundwater flow systems to saline seeps. Alfalfa cultivars differ in rooting depth, soil water extraction and yield based on their type of rooting system. The type of rooting system also affects how the alfalfa performs in different soil zones. To improve adoption and increase economic returns from alfalfa for salinity control, producers should have research information on which alfalfa cultivars give the best rooting depth along with the highest yields. Current recommendations on alfalfa cultivars for salinity control are based on research done in Montana before 1980, when many of today's improved varieties were not available.

Division Key Results: This project will contribute to improving soil quality by encouraging alfalfa production in dryland crop rotations. This will benefit the soil and the surrounding landscape by controlling salinity, reducing soil erosion and adding nitrogen and organic matter to the soil.

Project Description: Three sites were selected for this study. Site 1 is in the brown soil zone on the CARA research site near the Town of Oyen. Site 2 is located in the dark brown soil zone at the Lethbridge Research Station near Lethbridge. Site 3 is located in the black soil zone on the PARI Farm approximately 80 km east of Edmonton. Plots were seeded in 1994 with twelve varieties of alfalfa, randomized and replicated four times. One fallow plot was established in each replication to serve as a control. Each plot is 2m by 6m in size. Each plot was instrumented with a centrally located, 6m long by 5 cm diameter aluminum access tube to allow for the reading of soil moisture at depth. Soil moisture was read spring, summer and fall throughout the growing season using the neutron scatter technique. Readings were taken at 25 cm, 50 cm and every 50 cm thereafter to a depth of 5.5 m. Plots were harvested twice annually, in late spring and early fall and dry matter yields were determined.

Total Alfalfa Cultivar Yield for Three Sites and Three Locations.

Cultivar	Lethbridge			Oyen			Mundare		
	1995	1996	1997	1995	1996	1997	1995	1996	1997
120	9839	7129	9523	9097	2277	2092	5470	6062	4184
ACBlueJ	10385	7471	10767	9253	4098	3759	5733	6837	4311
Algonquin	10001	7303	11330	8794	4394	3999	4762	6627	4502
Anchor	9552	6642	9465	9258	4399	2966	6543	6790	4167
Apica	8692	6249	9405	8086	2922	2803	5364	5396	3504
ACBarrier	9799	6419	9425	10692	5616	3506	5645	7613	3997
Beaver	10217	6827	11637	9938	3424	3326	5375	6010	4191
Heinrichs	9202	5309	9418	9549	5223	3202	5820	6947	3777
Multigem	9973	6886	10735	8537	2691	2850	4800	5789	3491
Pioneer 532	10198	7278	11451	8366	2102	2502	5326	5770	3605
Rangelander	8499	5620	8387	11207	5488	3094	4780	6854	3768
Spredor II	9982	5770	10141	8966	4307	2657	4252	6890	4267
Mean	9695	6575	10140	9312	3913	3063	5323	6465	3980
LSD	1070	1658	2059	1249	868	732	903	823	550

Conclusion: The cultivars are very sensitive to precipitation and yields respond accordingly. The rhizomatous cultivars respond better in the dryer regions and the tap rooted cultivars respond better in the moister regions. The LSD value in the last row indicates statistical differences among cultivars. Forage quality is also being evaluated as part of this studied. The moisture use and rooting depths are still being calculated. This study has three more years until completed.

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